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1903

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IMPERIAL BUREAU OF MYCOLOGY
28 JUN. 1921

Indian Forester, XXIX, Appendix Sct.,
8 pp. 1903.

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CRYPTOGAMIC BOTANIST TO THE GOVERNMENT OF INDIA.

CALCUTTA:

OFFICE OF THE SUPERINTENDENT OF GOVERNMENT PRINTING, INDIA.

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21-X-15.

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In June 1902, I was sent by Mr. J. W. Oliver, I.F.S., specimens of a nearly dead young deodar from the Jaunsar forests, showing the stump with a number of roots attached, and a section from the middle of the stem. Mr. Oliver wrote that the trees were dying from what appeared to be a definite disease. His description was as follows. "One young tree generally dies first and then the disease spreads to other trees near it. It mostly attacks trees six to fifteen feet high. The first symptom is an exudation of resin at different points along the stem, then the needles turn yellow and fall off. It seems to take about two years to die completely." With the specimens were sent some sporophores of a fungus found by Mr. Oliver on the stem of a young deodar and said by him to be present on numbers of apparently healthy trees, as well as on some which showed the resin flux which is the first symptom of the disease. The fungus was probably a species of *Stereum*, but there was nothing to lead one to suppose that it was connected with the disease.

However the stump sent showed definite signs of having been killed by a parasitic fungus. Even in the absence of sporophores and without any experiments to demonstrate the cause of death, it is not impossible to

decide, from the structure of the diseased wood and from microscopic examination, that death has resulted from the action of a parasitic fungus, especially in the case of coniferous trees. The rot produced by the action of parasitic fungi before the death of the tree is, as Hartig has shown, characteristic of the particular fungus at work, in many cases, and different from rotting due to physiological causes and from that which occurs *post-mortem*. The principal diagnostic features are the presence of mycelial strands and sheets visible to the naked eye, as in trees attacked by *Polyporus sulphureus*; of peculiar white spots or streaks in the wood, as in *Stereum frustulosum* (*Telephora perdix*) and *Fomes annosus*; and of certain definite tissue changes visible under the microscope. Even where the parasite is one and the same, however, the symptoms produced by it vary according to the host plant. Thus *Trametes pini* produces changes which are quite different in the larch from those which the same fungus produces in the spruce. Unfortunately the forest diseases of India have not been investigated in the way that those of Europe have and the symptoms of fungus diseases of indigenous forest trees are not known. It is, therefore, not possible in the absence of fully developed sporophores to do more than state that the tree has been attacked before death by a parasitic fungus.

Further specimens received this year from the same district from Mr. B. Coventry, I.F.S., filled up the gap. They bore some particularly fine sporophores of *Fomes annosus* Fries, a fungus better known perhaps by Hartig's name of *Trametes radiciperda*. This fungus had been suspected by Mr. Oliver and myself last year, and Mr. Gamble in his "Manual of Indian Timbers" mentions it as one of the fungoid pests of the deodar.

Mr. Coventry's specimens corresponded exactly in the structure of the wood and the arrangement of the fungus mycelium, to those examined by me last year, and the mycelium could be traced without any difficulty to the fruiting organ. There can be little doubt, therefore, bearing in mind the virulent parasitism of this fungus, considered by Hartig to be the most dangerous

enemy of coniferous trees in Northern Europe, that it is the active agent in the disease in question. A curious fact in its biology is that it is mentioned by von Schrenk in quite a secondary place amongst the coniferous diseases of the new England States.

Fomes annosus, of which a good account will be found in Hartig's works and in Ward's "Timber and some of its Diseases," attacks *Pinus*, *Picea*, *Abies*, *Juniperus*, *Thuja*, and also the beech and some other dicotyledonous trees. Its destructive effects are most marked on the conifers. The form on *Cedrus Deodara* only will be here described and will be found to differ somewhat from the others.

Young trees are particularly mentioned by both Mr. Oliver and Mr. Coventry as suffering most, though in the pines in Europe trees of all ages are attacked. The underground portion is probably the first infected. Mr. Oliver's account of the centrifugal spread points to this, and it is in harmony with what has been observed elsewhere. The lateral roots become rotten, and are marked by characteristic white sheets and bands of mycelium between and under the bark scales. The bark cracks down to the cambium and may be lifted off in crusts separated from each other by sheets of mycelium. These sheets are delicate, but here and there they form thicker layers. In the European conifers small sporophores are derived from cushions of mycelium similarly developed and form the most characteristic peculiarity of the fungus. These underground sporophores were not found on any of the specimens examined by me. The latter were, however, few, and it is quite possible that a careful search amongst the roots of dead trees would bring them to light. Aggregations of mycelium representing, perhaps, the beginning of the formation of fruiting organs were found here and there on the bark of the roots. The root destruction is very complete. In one of Mr. Coventry's trees a single lateral root alone was found alive, which he concludes must have provided the whole root-nourishment of the tree. Of course a tree in this condition will not stand long. The first storm is pretty certain to bring it down.

It is probable that the root destruction may proceed far before the above-ground parts show the resin flux and fading of the needles noticed by Mr. Oliver.

The roots are not the only part affected. Broad bands of mycelium invade the collar, entering, so far as could be seen, in most cases, from lateral roots. These bands show an ascending growth, forcing their way along the cambial layer in feathery strands of delicate snow-white tissue (fig. 2). Since these destroy the cambium completely round the stump their effects must be disastrous, but in addition the wood is directly attacked and destroyed by fine hyphæ extending through its elements. In the roots the invasion of the wood is marked by violet brown streaks, which on section are seen to be due to browning of the wood parenchyma. Though under the microscope a commencement of similar browning of the cells of the wood parenchyma of the collar can be seen, their effect was not visible to the naked eye in any of the stems examined. Hence the red rot produced by this fungus in pine and spruce wood was not evident in deodar. Except for the white areas to be mentioned presently, no other discolouration was observed in the diseased wood.

The density of the wood is greatly diminished. Floated in water only about one-third of a block, which was advanced enough in the disease to show distinct white areas, was submerged; whereas in a block of fresh healthy deodar the upper surface was nearly flush with the water. Its toughness is also somewhat decreased, and splinters can be torn off without much effort. Its value as a timber must therefore be already considerably lessened before the disease shows itself fully.

One of the most characteristic features of the disease is the production in the wood of numerous white areas, usually somewhat elongated in the direction of the axis of the stem (fig. 3). At a later stage they become excavated into holes or cracks, but this is often obscured by the presence of a fringe of loose white fibres. The latter result from the action of the fungus in dissolving out the lignin elements from the wood cells, leaving only pure cellulose, and in destroying the middle lamellæ

between adjacent cells so as to isolate them from the rest of the tissue.

The hyphæ which penetrate the wood are extremely fine. Their effects on the tissues as disclosed by the microscope are as follows. The cells of the wood parenchyma and those of the medullary rays become browned. This action is most marked in the roots, which show violet-brown streaks on section. The interior of the cell becomes filled with a brown cloudy substance, probably resulting from the decomposition of the protoplasm since cells poor in protoplasm are not discoloured. Starch is unaltered till a late stage and may be seen immersed in the brown substance (fig. 4 a). In the stem, where the brown discolouration of the starch-bearing cells is much less visible, they may be seen, still loaded with starch, lying free amongst the fringe of isolated fibres and tracheæ which border the white areas. In and through all the elements scattered fine hyaline hyphæ pass, often so slender as to be made out with difficulty. Brown ones such as occur in the same disease in other conifers were not found. These bore their way freely from cell to cell, dissolving out sharply defined holes in the walls for their passage, which persist after the fungus filaments by which they were produced have themselves disappeared (fig. 4). In some places the wall may be seen to be perforated like a sieve by these holes.

The wood fibres and tracheæ are altered in a remarkable manner, apparently resulting from the selective action of ferments produced by the fungus on certain elements of the walls (fig. 4). The lignin elements (hadromal of Czapek) are removed. Pectose is probably also early dissolved. The white areas of diseased wood are formed of dissociated cells composed of practically pure cellulose and giving the blue reaction of the latter with iodine and sulphuric acid. The walls are marked with fine spiral striation, superposed walls giving a network from the crossing of the two spirals. The middle lamella, which consists largely of pectose, is dissolved so that the individual elements fall apart; they are eventually decomposed leaving small hollows in the wood,

lined with a white fluff of loose fibres. Before dissolution the wall cracks in large spiral cracks which, following the course of the striation mentioned above, are apparently always in a right ascending spiral (fig. 4 *c*). Longitudinal cracking does not occur. The spiral cracks are often seen, as an optical effect, crossing other cracks, chiefly, I think, of the opposite wall of the cell, in flattered elements, so as to produce an appearance of crossed cracks exactly like that figured by Hartig in wood attacked by *Polyporus Schweinitzii*. It is easy to see that these cracks owe their direction to the fine spiral streaking made evident by the lignin extraction and which must represent a fine spiral thickening of the lamellæ of the wall, the streaks being the lines where the edges of two lamellæ are approximated. Rupturing takes place naturally along these lines of least resistance.

The fruiting organ (sporophore) (fig. 1) arises from cushions of mycelium which force their way to the surface at the lower part of the trunk. These first appear as small rounded chocolate-brown nodules, which increase in number and run together forming a brown incrustation on the stem, broken by numerous irregular ledges and tubercles. On the under surfaces of some of these a white hymenial layer is developed. In the specimen figured in fig. 1, many small porous areas were found on the brown incrustation (*a a*) which composed the greater part of the sporophore. On this portion, however, all were old and of the same brown colour as the rest, with the pores partially filled up by a new hyphal growth from below, except one small white one apparently still active. At the time when it was obtained the main active portions of the spore-bearing organ were developed on a series of imbricated bracket-like protrusions (*b b*) from the upper part of the organ, where the trunk had curved away from the plane of the incrustation. These brackets measured $2\frac{1}{2}$ to 4 inches in breadth and projected about $1\frac{1}{2}$ to 2 inches from the stem.

The hymenial layer is white and covers the under-surface of the bracket partially with a thin white layer, leaving a band of brown sterile tissue round the edges.

The pores are irregularly rounded or elongated, and are in stratified layers, the new season's layer being alone active and distinct, while those of previous seasons are filled up by a new growth of hyphæ from the substance of the sporophore. The recent layer is thin and shows a tendency to turn rusty-brown as age advances. The sterile margin is variously ridged in more or less concentric ridges, marking possibly annual periods of growth, and is dotted with irregular tubercles. The upper surface of the bracket is also brown, roughened, tuberculate and concentrically ridged.

The most striking divergence presented by this fungus when compared with the form on other conifers and in other countries is the possession of *rhizomorphs*. One of these is figured in fig. 5. *Rhizomorphs* are well known in *Agaricus melleus* and *Dematophora necatrix*, two widely differed fungi, but have not been described in *Fomes annosus*. They are essentially tough bands of fungus-hyphæ converted into definite organs of propagation by a special arrangement of the fibres and by a power of apical growth. To the naked eye the deodar fungus *rhizomorphs* are not unlike the ordinary finer roots of the tree but much blacker and of a different consistence. They are branched, cylindrical or flattened bodies, of uneven diameter not diminishing regularly as roots do, composed of an outer, black, somewhat brittle cortex, and a central, very tough and flexible, whitish medulla. The cortex is often cracked, and where the strand runs along the surface of the stump white sheets of mycelium are often found adhering to it laterally, but not, I think, organically connected. On breaking one of them and teasing out a portion, the true nature of the organ is at once apparent. The medulla may be separated into fine silky filaments, which under the microscope are found to be hyaline hyphæ, while the cortex consists of a tissue of brownish tough hyphæ woven into a pseudoparenchyma.

Numbers of these *rhizomorphs* were found adhering to the diseased stumps. Several of them extended to the base of the sporophores, which, from Mr. Coventry's photographs, are evidently formed just at the level of the surface of the ground. Some were traced under the

cortex of the stump and were there found to expand into subcortical *rhizomorphs* of a looser consistence than the external ones and with their cortex intimately connected with the tissues of the deodar. From these subcortical *rhizomorphs* the broad sheets of mycelium above described can be seen to extend.

The occurrence of this form of external subterranean mycelium adds to the probability of the disease being conveyed underground from tree to tree. *Rhizomorphs* are, in fact, organs of vegetative reproduction admirably adapted to life under-ground. Even where the roots of adjacent trees do not come into contact, the *rhizomorph* can bridge over a space of probably many inches to spread the disease. *Fomes annosus*, so far as has hitherto been known in other lands, has relied mainly on actual contact for its extension and in a secondary degree on reproduction by spores. The large quantity of rhizomorphs found on the deodar shows that these must form the chief mode of propagation in India, and the discovery of these organs indicates a greater capacity for damage than in any other instance in which this fungus is known as a forest pest.

Hence treatment is not hopeful. The *rhizomorphs* cannot readily be destroyed. Isolation of diseased trees by trenching is the only method likely to be successful. Such a treatment is advocated in Germany, but it appears to be doubtful if it can be carried out profitably on a large scale. The removal of sporophores from the stem is probably a measure of quite secondary importance.

Although treatment may not be practicable on a large scale in the forest, it is beyond doubt that it might become extremely useful in municipalities or bungalow compounds, where the value of the tree from an ornamental point of view is the chief consideration, and where an outbreak of this disease might cause damage which could not easily be repaired. In such a case early removal of the tree after death to prevent the formation of sporophores, and running a trench a few feet in depth round the stump sufficiently far out to include the larger roots, are measures which could easily be carried out and should serve to prevent the mischief extending.

G. I. C. P. O.—No. 1476 R. & A.—27-10-1908.—650.—G. R.

EXPLANATION OF THE FIGURES.

FIG. 1. Sporophore of *Fomes annosus* on deodar showing the brown tuberculate incrustation, and bracket-like active portion with white hymenium below, *a a* brown, mostly sterile portion; *b. b.* recent, sporeforming portion.

,, 2. White mycelial sheets under the bark of the collar.

,, 3. Drawing of a portion of the surface of a block of wood cut from a diseased tree, showing the white areas in the wood.

,, 4. Tissue elements modified by the action of the parasite. *a. a.* cells of the wood-parenchyma-bearing starch; *b.* bore-holes of the hyphæ with a filament extending across between two. *c.* spiral cracking of the wall. *d.* pitted vessel with a hypha penetrating it. *e.* network from the crossing of two spirals, the trachea is seen with the upper wall removed, so that the network is made up of the spiral of the lower wall of this trachea and that of the upper wall of the subjacent one. *f.* dissolution of the middle lamella which results in the isolation of the elements.

,, 5. A rhizomorph.

H. Hormusji del.

Lith: by A.C. Chowdhary.

FOMES ANNOSUS Fr.

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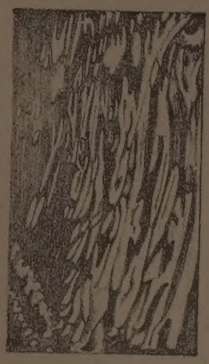

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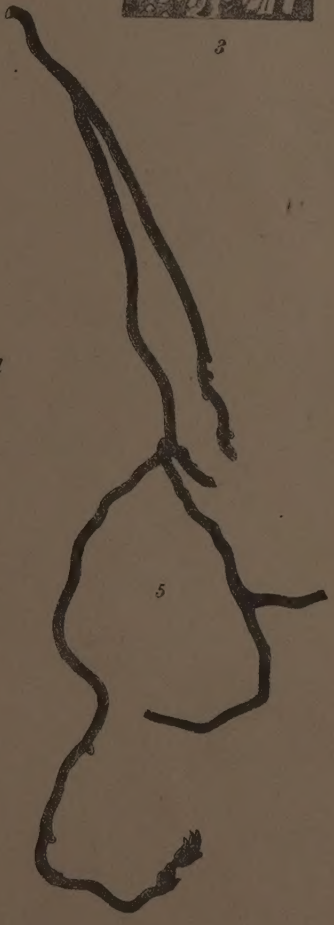

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